Short Communication

Above-ground biomass and plant cover in a succulent shrubland in the southern Karoo, South Africa

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The above-ground, air-dry mass of vegetation in a succulent Karoo shrubland inland of the Swartberg mountains (33°S 22°E) in the southern Cape averaged 3.27 metric tons ha^{-1}, of which 6% was necromass. Linear regression equations relating fresh and dry above-ground biomass to projected canopy cover are presented. Above-ground biomass of succulent Karoo shrublands is comparable with other karroid vegetation types but less than mature vegetation in the adjacent Fynbos shrublands. Plant cover and biomass values for parts of the Mojave Desert (36°S 117°W), North America, are similar to the succulent Karoo shrubland, but the two vegetation types differ in the relative contributions of succulent and non-succulent plants, and in the average sizes and spacing of plants.

Die bogrondse droëmassa van plantegroei in 'n Karoo-sukkulentstruikveld op die binnelandse kant van die Suid-kaapse Swartbergreeks (33°S 22°O), het 'n gemiddelde waarde van 3.27 metrieke ton ha^{-1}, waarvan 6% nekromassa is. Die verhouding tussen vars- en droëbogrondse massa en kroonuitgestrektheidsbedekking is lineêr. Bogrondse fitomassa van Karoo-sukkulentstruikveld is soortgelyk aan ander Karooveldtipes maar laer as aangrensende volwasse Fynbos-struikveld. Plantbedekking en fitomassa van dele van die Mojave Woestyn (36°S 117°W), Noord-Amerika, kan vergelyk word met Karoo-sukkulentstruikveld, maar hierdie veldsoorte verskil in die relatiewe hoeveelheid vetplante, in die gemiddelde groottes van plante en hul plantspasiëring.

Above-ground plant biomass has been sampled in all the South African biomes (Rutherford & Westfall 1986), but few standing crop or biomass accumulation measurements have been made in the Succulent Karoo (Werger 1985). The cover and biomass figures presented here for the Tierberg Karoo Research Centre field site, serve as a baseline for plant recolonization and biomass accumulation studies being carried out at this site.

The Tierberg Karoo Research Centre (33°10′S, 22°17′E) near Prince Albert, is situated in a fold valley on the southern edge of the Great Karoo (more fully described in Milton *et al.* in press). The weakly structured, sandy-loams are alkaline and typical of soils of low-lying positions in arid regions (Ellis & Lambrechts 1986). The average annual rainfall for 92 years at Prince Albert (25 km to the west) is (mean ± *SE*) 167 ± 7 mm. Venter *et al.* (1986) place Prince Albert in a between-seasons rainfall zone, with 50–60% of the annual total rain falling in summer. Temperatures are extreme with daily maxima exceeding 30°C between December and March and daily minima below freezing for about 10 days annually (Venter *et al.* 1986). The prevailing westerly wind probably increases the desiccating effects of the summer heat.

Twenty plots (each 5 m × 2.5 m) were laid out at 100-m intervals along two 1-km transect lines running east to west across plains in the northern quarter of the study site. Sampling was carried out between 25 June and 11 July 1989. The moisture status of the vegetation appeared normal for the time of the year, and rainfall in the 3-month period preceding sampling was as follows: April 39 mm, May 0 mm, June 20 mm. Plant cover was estimated by measuring intercepts of all plant species along four 5-m line transects per plot. All plants were then cut at ground level, sorted into species and weighed in the field. Subsamples of 14 succulent and 11 non-succulent plant species and of dead wood were frozen for 6 weeks to stop metabolic processes and to burst cells, then air dried to constant weight at room temperature for 6 months. The samples were reweighed in January (ambient temperature 3°C, humidity 20%) to obtain an estimate of water content (Table 1). Cover-biomass regressions and estimates of the standing biomass of the plains shrubland (Table 2) were calculated from these data. The mean difference between the estimated moisture contents of air-dried and oven-dried (24 h at 70°C) shrub samples was 6.8% (± *SE* 1.4, $n = 8$).

Moisture contents ranged from 25 to 73% in non-succulent species and from 42 to 87% in succulent species. The above-ground parts of short-lived and shoot-deciduous species contained more moisture than the stems and leaves of long-lived, evergreen shrubs (Table 1). This trend held for both succulent and non-succulent species. Succulents absorb water rapidly becoming turgid within 24 hours of rain (pers. obs.) and they 'tie up' some 2 660 litres of water per hectare (fresh mass of succulents averages 4 011 kg ha^{-1} of which 66.3% is water). These features presumably enable them to compete successfully with annual forbs and non-succulent shrubs in arid areas which receive a number of small rainfall events rather than predictable heavy rains.

The total above-ground (dry) biomass of plains vegetation at Tierberg, 3.27 metric tons ha^{-1} (Table 2), was within the range (0.5 to 7.6 metric tons ha^{-1}) reported for the Succulent and Nama Karoo Biomes (Rutherford 1978; Rutherford & Westfall 1986), but well below the 6 to 25 t ha^{-1} of shrublands in the nearby Fynbos Biome (Rutherford & Westfall 1986). Projected canopy cover averaged (mean ± *SE*) 25.6 ± 1.4% (range 17 to 31%) for the succulent shrubland at Tierberg. Although this is low by comparison with cover values in grassy False Upper Karoo at Middelburg (71% and 76% on north- and south-facing slopes respectively), biomass values are similar: 2.54 t ha^{-1} on north-facing and 4.29 t ha^{-1} on south-facing slopes (Roux 1988). Differences in productivity and turnover in these two vegetation types are expected to be great, because Middelburg receives 365 mm rain annually, over twice as much as Prince Albert.

There were significant ($P < 0.01$, $df = 18$) correlations between total projected canopy cover and total fresh and dry above-ground biomass in 12.5-m^2 sample plots in plains vegetation at Tierberg. The following regression equations can be use to convert canopy cover values of plains

Table 1 Moisture contents of the above-ground parts of plant species harvested in June 1989 from plains vegetation at Tierberg Karoo Research Centre, in the southern Karoo. Moisture content given as a percentage of the original fresh weight after air-drying

Species	Sample number	Moisture % mean (*SE*)	Structural attributes
Necomass			
dead non-succulent	3	5.8 (1.9)	
dead succulent	3	4.9 (1.9)	
mean % water in necromass	6	5.3 (1.3)	
Non-succulent plant biomass			
Gazania krebsiana Less.	1	73.1 (—)	shoot-deciduous non-woody
Lotononis versicolor (E. Mey) Benth.	2	62.8 (—)	shoot-deciduous non-woody
Osteospermum sinuatum (DC.) T. Norl.	6	59.6 (4.1)	leaf-deciduous woody
Felicia muricata (Thunb.) Nees	1	45.3 (—)	shoot-deciduous non-woody
Protasparagus aethiopicus L.	1	43.2 (—)	shoot-deciduous non-woody
Chrysocoma ciliatus L.	1	32.1 (—)	evergreen non-woody
Felicia filifolia (Vent.) Burtt Davy	1	30.0 (—)	semideciduous woody
Galenia fruticosa (L.f.) Sond.	5	29.4 (12.3)	semideciduous woody
Salsola tuberculata (Mog.) Fenzl	1	29.2 (—)	evergreen woody
Pteronia pallens L.f.	4	28.7 (5.2)	evergreen woody
Pteronia empetrifolia DC.	5	25.8 (3.0)	evergreen woody
Mean % water in 11 non-succulent spp.		41.7 (5.3)	
Succulent plant biomass			
Augea capensis Thunb.	1	87.0 (—)	shoot-deciduous non-woody
Nalephora lutea Schwant.	1	85.5 (—)	short-deciduous non-woody
Aridaria nudflora (L.) Schwant.	1	81.1 (—)	leaf-deciduous woody
Crassula muscosa L.	2	78.7 (—)	shoot-deciduous non-woody
Sphalmanthus brevifolius (Haw.) N.E. Br.	1	72.3 (—)	leaf-deciduous woody
Rhinephyllum macradenium (L. Bol.) L. Bol.	4	64.7 (15.0)	evergreen non-woody
Crassula subaphylla (Eckl. & Zeyh.) Harv.	1	64.4 (—)	evergreen non-woody
Tetragonia spicata L.f.	5	63.6 (3.0)	leaf deciduous woody
Hereroa latipetala L. Bol.	4	63.6 (5.5)	evergreen woody
Brownanthus ciliatus (Ait.) Schwant.	3	62.4 (11.5)	leaf-deciduous non-woody
Ruschia approximata (L. Bol.) Schwant.	4	59.8 (7.4)	evergreen woody
Eberlanzia sp.	5	58.3 (8.7)	evergreen woody
Drosanthemum montaguense L. Bol.	3	45.3 (11.7)	semideciduous woody
Rhinephyllum graniforme (Haw.) L. Bol.	1	41.6 (—)	evergreen woody
Mean % water in 14 succulent spp.		66.3 (3.7)	

vegetation at the Tierberg site to biomass values:-

fresh mass kg ha^{-1} = 0.8 [302.99 cover (%) + 1275];

dry mass kg ha^{-1} = 0.8 [161.32 cover (%) – 45).

If biomass of vegetation is a function of effective rainfall, the length of the growing season and vegetation history, then biomass values for undisturbed vegetation on sites which

Table 2 Above-ground fresh and air-dry biomass values (means and standard deviations) for vegetation from 20 harvested 12.5-m^2 plots at Tierberg Karoo Research Centre. Cover estimates are based on four line transects per plot and include dead material

	Succulents	Non-succulents	Dead material	Total
Projected cover (%)	10.8 (2.6)	13.7 (5.3)	1.2 (1.4)	25.6 (6.2)
Fresh mass (g $plot^{-1}$)	5014 (1576)	3722 (1865)	297 (446)	9033 (2859)
Air-dry mass (g $plot^{-1}$)	1689 (531)	2169 (1087)	281 (422)	4085 (1546)
Air-dry mass (kg ha^{-1})	1351	1735	225	3268
Percentage of total	41%	53%	6%	

differ little in latitude, altitude, topography or total rainfall, should be very similar. Vegetation at Mercury, Nevada (36°S 117°W; 1 060 m a.s.l.) in the Mojave desert, North America, a climatically similar site with a non-seasonal rainfall of 100 to 200 mm p.a., and alkaline soils (McMahon & Wagner 1985), resembles the southern Karoo shrubland in terms of biomass and cover. Above-ground biomass of perennial vegetation in the North American asteraceous shrublands is 2.96 to 5.58 t ha^{-1} and vegetation cover ranges from 22 to 38% (Hunter & Medica 1989). Despite the similarites between the Karoo and North American sites, the relative contributions of the various lifeforms to total biomass differed. Succulents comprised 41% of the biomass at the Karoo site but were rare at sites sampled in the Mojave Desert. On the other hand, ephemerals at times added about 200 kg ha^{-1} to the above-ground biomass in the Mojave but were rare at the southern Karoo site at all seasons regardless of rainfall (pers. obs.). A detailed study of the physical and chemical properties of soils may provide some clue to differences in the relative abundance of these lifeforms, as well as to differences in the sizes and spacing of plants. Plants are smaller in the southern Karoo site (maximum height 58 cm, mean height ($\pm SE$) is 15 ±1 cm, mean diameter ($\pm SE$) is 23 ±1 cm than in the Mojave where some shrubs exceed 110 cm in height and diameters average 32 cm ($\pm SE$ 2 cm). Shrub density at Tierberg ranges from 3 to 7 shrubs m^{-2}, compared with densities of 1 to 4 shrubs m^{-2} at the Nevada site (Hunter & Medica 1989).

Studies of above-ground biomass alone may give a biased picture of interactions between plants and of the resources available to herbivores. Scott & van Breda's (1939) pioneering studies of roots of Karoo plants suggest that below-ground phytomass and root 'cover' may well be greater than that of the shoots. Root biomass and production studies would enable us to interpret trends observed in above-ground biomass of Karoo vegetation.

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